PNM San Juan Generating Station
Review of Inherent SO$_3$ Removal Scenarios and Sorbent Injection for SO$_3$ Removal
March 16, 2009

Introduction

On December 29, 2009, the New Mexico Environment Department (NMED) requested additional information regarding acid mist (SO$_3$) emissions from Public Service of New Mexico (PNM) for the San Juan Generating Station (SJGS) BART analysis. After follow up discussions with the NMED in a conference call held on January 14, 2009, it is PNM's understanding that NMED requests the following information:

- A BART visibility modeling analysis for the SCR and Hybrid SNCR/SCR systems that shows the effect of inherent removal of SO$_3$ generated from those technologies (i.e., SO$_3$ generated from the conversion of SO$_2$ to SO$_3$ across the SCR catalyst) at the Class I areas. The inherent removal of SO$_3$ is based on the existing air pollution control devices.

- A BART analysis (engineering and visibility modeling) for the SCR and Hybrid SNCR/SCR systems that shows the combined effect of inherent removal of SO$_3$ generated from those technologies and the removal of SO$_3$ by the installation of sorbent injection control technology.

The purpose of this report is to provide a summary of engineering information which pertains to each of the above scenarios and the resulting class I visibility impacts associated with each scenario.

Review of SO$_3$ Control Technology References Provided by NMED

As part of NMED's review of the PNM BART analyses, NMED reviewed technical papers discussing SO$_3$ control for coal-fired power plants. These references formed part of the basis for NMED's request for additional information on SO$_3$ at SJGS. The following references were reviewed:

- Estimating Total Sulfuric Acid Emissions from Stationary Power Plants (EPRI)
- A System Approach to SO$_3$ Mitigation (B&W)
- Emissions of Sulfur Trioxide from Coal-Fired Power Plants (Babcock Power)
- SO$_3$ Impacts on Plant O&M: Part 1 (Power Magazine)

PNM has reviewed these references and has the following general comments.

NMED EX. 7p

Amount of SO$_3$ Oxidation.

SO$_3$ conversion in the SCR catalyst was estimated at 1.0 percent for 3 layers. This equates to catalyst conversion of 0.33 percent per layer. A more aggressive conversion rate of 0.1 percent was not possible due to the high ash content of the SJGS coal.

SO$_3$ Removal in Air Heater

Removal of SO$_3$ in the air heater as estimated by each reference is dependent on operating the regenerative air heater at a cold-end metal temperature that is below the acid dewpoint temperature. Condensation of H$_2$SO$_4$ aerosols will occur at this low temperature. The operation of the air heater below the acid dewpoint temperature should be avoided at SJGS to prevent corrosion issues from the acid condensation on the air heater surfaces and to prevent the formation of ammonium sulfates and ammonium bisulfates (with ammonia slip from SCR) that plugs the air heater. Therefore, the expected 40 percent removal of SO$_3$ in the air heater as indicated in these references is not a desired or plausible method of operation at SJGS.

SO$_3$ Removal in PJFF

The amount of SO$_3$ removed in the PJFF is dependent on the alkalinity of the fly ash. This is because SO$_3$ is adsorbed onto fly ash particles collected in the PJFF, and neutralized by the alkaline constituents in the fly ash. Finally, it is removed in the PJFF with the collected fly ash. SO$_3$ in the flue gas stream is in a vapor form and will pass through the PJFF. For high alkaline (20 to 30 percent by weight) fly ash, a high removal of SO$_3$ is expected. However, for low alkaline fly ash such as SJGS (8 percent by weight), removal of SO$_3$ in the PJFF will be similar to that for bituminous coal, which is a maximum of 40 percent by weight. B&W had predicted an inherent SO$_3$ removal of 50 percent for the PJFF at SJGS.

SO$_3$ Removal in FGD

Removal of SO$_3$ in the FGD system is limited by the size of the H$_2$SO$_4$ particles in the FGD. At SJGS, only the larger particles will be captured, while sub-micron particles will escape the FGD. All the references list an average SO$_3$ removal of 50 percent by the FGD system. B&W had predicted an inherent SO$_3$ removal of 40 percent for the FGD at SJGS.

Part 1 - Engineering Impact Analysis

As requested by NMED, analyses were performed to determine the amount of SO$_3$ emissions that could be inherently removed through the use of existing equipment or

air pollution controls at the SJGS or through the installation of additional technologies. The following sections briefly discuss the available and technically feasible options, control effectiveness, and cost of those options.

<u>Available and Technically Feasible SO_3 Control Technologies</u>

1. Inherent Removal

Inherent removal is defined as the capture of SO_3 from flue gas by the existing pollution control equipment installed for SO_2 and PM reduction. For SJGS, the existing pollution control equipment is the wet limestone SO2 scrubbing system and the PJFF (baghouse). The co-benefit removal of SO_3 was calculated for the additional SO_3 generated from the oxidation of SO_2 by the SCR catalyst. The SO_3 emission rates for the existing pollution control equipments was calculated using the National Park Service (NPS) formulas which accounted for inherent removal of the SO_3 generated in the boiler by the consent decree equipments.

2. Sorbent Injection SO_3 Removal

Sorbent injection removes SO_3 in the flue gas by reaction of the SO_3 with an alkaline sorbent material to form a particulate that is subsequently removed in a particulate control device. The alkaline material injected can be a magnesium-, sodium-, and calcium-based sorbent. The injection points for the reagents may vary. For this analysis, hydrated lime was selected. For SJGS, hydrated lime is considered to be equivalent to other sorbents for removal performance. Attachment 1 shows the design concept definition of the sorbent injection system.

3. Wet Electrostatic Precipitator (WESP)

A WESP is typically installed downstream of a wet FGD and collects particles based on the same principle as a dry ESP; negatively charged particles are collected on positively charged collecting surfaces. However, a WESP uses a wet collecting surface that is flushed with water. While the WESP is primarily a particulate matter collection device, the nature and use of WESP allows sulfuric acid mist (SO_3) to condense and be collected as particulate or absorbed into the water stream along the charged collection surfaces. This co-benefit removal drove the use of a WESP for acid mist collection as one of the earliest applications of the ESP technology.

The BART modeling analysis submitted on August 29, 2008 included WESP as an additional PM control device. The analysis included the co-benefit removal of SO_3 by the WESP. Therefore, the WESP will not be considered again in this analysis.

<u>Control Effectiveness</u>

To calculate the inherent control of SO_3 produced by the SCR catalyst, B&V utilized the performance information provided for the consent decree by B&W. This information is shown in Attachment 2 and is based on mass balances that were provided as part of the contracts and performance guarantees from B&W. These data indicate an expected 50 percent removal in the PJFF and 40 percent removal in the FGD system. It should be noted that an error exists in the original reports with regard to the SO_2 stack outlet emission rates from the Unit 1 & 2 and Units 3 & 4. The SO_2 stack outlet emission rates from the Unit 1 & 2 and Units 3 & 4 should reflect 550 lb/hr and 860 lb/hr, respectively. This data, contained in Attachment 2, has been corrected for this submittal to reflect the correct SO_2 stack outlet emission rates.

For the sorbent injection cases, an emission rate of 0.004 lb/MBtu was used. This emission rate was determined to be the lowest achieved emission level. This emission level is converted to a mass emission rate using the unit heat input rates established in the stack outlet conditions in Attachment 3.

As stated above, four cases were investigated to determine the engineering impact of SO_3 control at San Juan Generating Station. The following is a description of each scenario (with summary of SO_3 emission rates in Table 1) that was evaluated:

1. Control of SO_3 Produced by the SCR through Inherent Controls

Inherent removal of SO_3 generated from the oxidation of SO_2 by the SCR catalyst by the existing pollution control equipment was calculated. The SO_3 emission rate for the existing pollution control equipment was calculated using the National Park Service (NPS) formulas, which accounted for inherent removal of the SO_3 generated in the boiler.

2. Control of SO_3 Produced by the SNCR/SCR Hybrid through Inherent Controls

Inherent removal of SO_3 generated from the oxidation of SO_2 by the SNCR/SCR Hybrid catalyst by the existing pollution control equipment was calculated. The SO_3 emission rate for the existing pollution control equipment was calculated using the National Park Service (NPS) formulas, which accounted for inherent removal of the SO_3 generated in the boiler.

3. Control of SO_3 Emissions from SCR through Sorbent Injection

In this scenario, in addition to inherent removal of SO_3 by the existing pollution control equipment, sorbent injection is also added to further remove SO_3 from both the boiler and SCR catalyst.

4. Control of SO_3 Emissions from SNCR/SCR Hybrid through Sorbent Injection

In this scenario, in addition to inherent removal of SO_3 by the existing pollution control equipment, sorbent injection is also added to remove SO_3 from both the boiler and SNCR/SCR Hybrid catalyst.

Unit	Existing Pollution Control Equipment SO_3 Outlet (lb/hr)	Additional SO_3 from Catalyst Conversion (lb/hr)	Stack SO_3 Outlet (lb/hr)[a]
Table 1 **Summary of SO_3 Emission Rates**			
Inherent Controls on SCR			
SJGS 1	40.50	73.66	62.60
SJGS 2	40.30	73.66	62.29
SJGS 3	62.90	114.42	97.22
SJGS 4	61.70	112.25	95.37
Inherent Controls on SNCR/SCR Hybrid			
SJGS 1	40.50	73.66	62.60
SJGS 2	40.30	73.66	62.29
SJGS 3	62.90	114.42	97.22
SJGS 4	61.70	112.25	95.37
Control of SO_3 from SCR Catalyst Conversion Using Sorbent Injection			
SJGS 1	40.50	73.66	16.09
SJGS 2	40.30	73.66	16.01
SJGS 3	62.90	114.42	24.99
SJGS 4	61.70	112.25	24.52
Control of SO_3 from SNCR/SCR Hybrid Catalyst Conversion Using Sorbent Injection			
SJGS 1	40.50	73.66	16.09
SJGS 2	40.30	73.66	16.01
SJGS 3	62.90	114.42	24.99
SJGS 4	61.70	112.25	24.52

[a] Stack SO_3 outlet emission rate considers additional control of this pollutant through inherent control or inherent control and sorbent injection.

<u>Cost Effectiveness</u>

Attachment 4 shows the detailed cost estimate development for the sorbent injection system. Table 1 in Attachment 5 shows the cost effectiveness of SO_3 controls for the SCR and SCR/SNCR Hybrid. The cost effectiveness values shown in the table are in dollars per ton of SO_3 removed.

Part 2 – Visibility Analysis

Subsequent to the June 6, 2007 submittal, PNM further investigated additional refinements to the BART CALPUFF air dispersion modeling analyses which included nitrate repartitioning and more realistic ammonia background concentrations based on monitored values at several western Class I areas. These additional modeling options are considered more realistic and therefore will again form the basis of this analysis.

To date, PNM has previously submitted five BART modeling analyses in addition to the SO_3 analysis being submitted coincident as part of this analysis. A summary of each analysis is provided below:

<u>June 6, 2007</u>

Modeling analyses were performed to provide SJGS plant-wide regional haze (visibility) impacts at 16 Class I areas. The analyses were based on a constant 1 ppb background ammonia concentration and no nitrate repartitioning. The NO_x control technologies analyzed were the Selective Catalytic Reduction (SCR) and SNCR/SCR Hybrid.

<u>November 6, 2007</u>

Modeling analysis were performed to provide SJGS plant-wide regional haze (visibility) impacts at 16 Class I areas. The analyses were based on refinements which included using the nitrate repartitioning methodology and monthly variable background ammonia concentrations. Again, the NO_x control technologies analyzed were the SCR and SNCR/SCR Hybrid.

<u>March 31, 2008</u>

Two main modeling analyses were performed to provide SJGS plant-wide and unit specific regional haze (visibility) impacts at 16 Class I areas for the SCR NO_x control technology only. One of the analyses, believed to be the more representative of ammonia chemistry of the area, was based on the November 6,

2007 refinements which included using the nitrate repartitioning methodology and monthly variable background ammonia concentrations. The other analyses included nitrate repartitioning and a constant background ammonia concentration as requested by the NMED.

May 30, 2008

Two modeling analyses were performed to provide SJGS plant-wide and unit specific regional haze (visibility) impacts at 16 Class I areas for the SNCR NO_x control technology only. Similar to the March 31, 2008 analyses, one of the analyses was based on the November 6, 2007 refinements that included using the nitrate repartitioning methodology and monthly variable background ammonia concentrations. The other analyses included nitrate repartitioning and a constant background ammonia concentration. It should be noted that all vendors of SNCR (including Fuel Tech and Nalco Mobotec) have been modeled together as one technology called SNCR. This is the same approach that is used for modeling SCR control technology, where all vendors are modeled generically as SCR.

August 29, 2008

Three modeling analyses were performed to provide SJGS plant-wide and unit specific regional haze (visibility) impacts at 16 Class I areas for the ROFA with Rotamix, Rotamix, and ROFA NO_x and WESP PM control technologies (the NO_x and PM analyses were submitted separately). Similar to the May 30, 2008 analyses, these analyses were also based on the November 6, 2007 refinements that included using the nitrate repartitioning methodology and monthly variable background ammonia concentrations.

March 16, 2009

Four modeling analyses were performed to provide SJGS plant-wide and unit specific regional haze (visibility) impacts at 16 Class I areas. These include the following:

- SCR technology with inherent SO_3 removal of the SO_3 formed from the catalyst oxidation of SO_2 to SO_3.
- SCR/SNCR hybrid technology with inherent SO_3 removal of the SO_3 formed from the catalyst oxidation of SO_2 to SO_3.
- SCR technology with inherent SO_3 removal of the SO_3 formed from the catalyst oxidation of SO_2 to SO_3 and sorbent injection.

- SCR/SNCR hybrid technology with inherent SO_3 removal of the SO_3 formed from the catalyst oxidation of SO_2 to SO_3 and sorbent injection.

Similar to the August 29, 2008 analyses, these analyses were also based on the November 6, 2007 refinements which included using the nitrate repartitioning methodology and monthly variable background ammonia concentrations.

Visibility Summary

Based on the refined methodology consisting of representative background ammonia concentrations and nitrate repartitioning, revised CALPUFF visibility modeling was performed for four cases; SCR (inherent control), SCR/SNCR Hybrid (inherent control), SCR (inherent and sorbent control), SCR/SNCR Hybrid (inherent and sorbent control) technology scenarios. The modeling summarized in this report is for the SJGS on a plant-wide basis and for each of the four SJGS units on an individual unit basis. It is important to note that all other modeling options as described in the BART application were unchanged. For simplicity, the following results discuss the differences between the consent decree scenario and the control technology scenarios.

The stack outlet conditions for the control technology scenarios are included in Attachment 3. These tables reflect the information from the previous submittal and have not been modified to illustrate the changing stack outlet SO_3 emissions indicated in Table 1 above. Attachment 6 includes both the facility and a unit specific summary of the 98th percentile visibility impact for the modeled scenarios, the number of days above 0.5 dv threshold, and the contribution of each pollutant associated with the 98th percentile visibility impact for each Class I area.

Additionally, a minor discrepancy was discovered in the previously submitted visibility modeling results for the SCR NO_x control technology scenario. Specifically, the NO_x stack outlet emission rate was correctly reflected in the stack outlet summary tables (based on 0.07 lb/MBtu) but the initial modeling reflected an incorrect NO_x stack outlet emission rate for each unit based on 0.06 lb/MBtu. This discrepancy was corrected, and the results reflected within the information contained in Tables 2 and 3 of this submittal. Two important points must be clarified with regard to this issue. First, as discussed in previous submittals, the NO_x emission rate of 0.07 lb/MBtu is the appropriate emission rate for retrofitted SCR technologies at SJGS as reviewed in the BART analyses and not the 0.06 lb/MBtu NO_x emission level. Secondly, as can be seen from the resulting visibility impacts for the SCR control scenarios for the NO_x emission rate of 0.07 lb/MBtu (Tables 2 & 3 below), the maximum visibility modeling results (over the period 2001 to 2003) are mostly unchanged for each Class I area if compared to previously submitted results for the same scenario. Thus, as described in previous

submittals and reiterated later in this document, the visibility degradation by sulfur emissions is more pronounced than from emissions of NO_x.

SJGS Facility Visibility Summary with SCR or SCR/SNCR Hybrid Utilizing Inherent Controls on the SO₃ Generated from the Catalyst

The results of the refined visibility modeling for the SJGS plant, assuming the same level of inherent control for all four units for each technology scenario, are illustrated in Tables 1-4 and 21-24 of Attachment 6. These tables summarize the scenarios and the maximum visibility (deciview) impact seen at any of the 16 Class I areas at any time over the 2001 to 2003 period. The results of this analysis, using the aforementioned refinements, indicates a minimal improvement in visibility impact (less than 0.5 dv) at each of the 16 Class I areas when compared to the baseline (consent decree) scenario. It should be noted that there was one instance in which the result exceeded the 0.5 dv threshold by 0.04 dv for the Capital Reef Class I area which is not located in New Mexico.

The maximum visibility (deciview) improvement seen at any of the 16 Class I areas at any time over the 2001 to 2003 period is illustrated in Tables 4 and 24 of Attachment 6 for each scenario. The expected degree of visibility improvement for each unit (on a plant-wide basis) was determined by the difference in the maximum visibility improvement for each receptor at each of the sixteen Class I areas. Again, it is important to note that the control technology associated with the consent decree formulated the SJGS's baseline case, as well as the baseline case for the individual unit analyses described later. Additionally, the cost-effectiveness for the potential BART control technologies from the BART application were used to calculate visibility improvement cost-effectiveness in $/deciview ($/dv). Three major scenarios are shown in the visibility improvement cost effectiveness summary in Tables 4 and 24 of Attachment 6 for each control technology:

- Pre-consent decree to consent decree.
- Consent decree to additional NO_x control technology alternative scenarios including inherent removal of SO_3.
- Pre-consent decree to additional NO_x control technology alternative scenarios including inherent removal of SO_3.

These maximum visibility improvements between the consent decree and the two NO_x control technology scenarios (SCR and SCR/SNCR Hybrid) with inherent SO_3 removal considered range from showing no improvement (i.e., visibility degradation at

Mesa Verde) at all to 0.54 dv of expected visibility improvement above the consent decree scenario. The visibility improvements for each of theses options are summarized below:

- Facility improvements with SCR and inherent SO_3 removal range from no improvement to 0.54 dv.
- Facility improvements with Hybrid and inherent SO_3 removal range from no improvement to 0.23 dv.

The results indicate that adding additional NO_x control technology beyond the consent decree and including consideration of inherent SO_3 removal through existing control technologies only results in one class I area visibility improvement greater than 0.5 dv and visibility degradation at Mesa Verde.

Based on the visibility improvement modeled and the total annual cost evaluated in the impact analysis stage of the BART application document, the cost-effectiveness for visibility improvement (annual cost per improvement in visibility, $/dv), was determined for SJGS over the aforementioned range of visibility improvement. The resulting cost for installation of either SCR or SCR/SNCR Hybrid NO_x control technology for all four units ranges from $1.2 billion/dv to $180 million/dv (excluding the scenarios where there was visibility degradation). The visibility improvements for each of the control technology options with inherent control are summarized below:

- SCR range from $487 million/dv to $180 million/dv.
- SCR/SNCR Hybrid range from $1.2 billion/dv to $365 million/dv.

Unit Specific Visibility Summary with SCR or SCR/SNCR Hybrid Utilizing Inherent Controls on the SO₃ Generated from the Catalyst

The results of the refined visibility modeling for Unit 1, Unit 2, Unit 3, and Unit 4 for the two control technologies utilizing inherent control assumptions are illustrated in Tables 5-20 and 25-40 of Attachment 6, respectively. These tables summarize the scenarios and the maximum visibility (deciview) impact seen at any of the 16 Class I areas at any time over the 2001 to 2003 period. Similar to results seen for the SJGS facility, the visibility impacts of individual units at Class I areas outside of New Mexico represent the maximum visibility impact at any of the 16 Class I areas. In addition, this analysis indicates a minimal improvement in visibility impact (less than 0.5 dv) at each of the 16 Class I areas when compared to the baseline (consent decree) scenario.

The maximum visibility (deciview) improvement seen at any of the 16 Class I areas at any time over the 2001 to 2003 period are illustrated for these two technologies in Tables 8, 12, 16, 20, and 28, 32, 36, 40 of Attachment 6. Again, the expected degree of visibility improvement for each control scenario for each unit was determined by the difference between the consent decree's maximum visibility improvement for each receptor at each of the sixteen Class I areas and the specific NO_x control technology (with inherent SO_3 removal considered) scenario's maximum visibility improvement for each receptor at each of the sixteen Class I areas. Furthermore, the same methodology previously described for the SJGS's cost-effectiveness in ($/dv) was used here for each unit.

These maximum visibility improvements between the consent decree and the NO_x control scenario for each unit are similar to that of the combined SJGS. The visibility improvements for each scenario are summarized below.

SCR with Inherent SO₃ Removal
- Unit 1 improvements range from 0.04 dv to 0.42 dv.
- Unit 2 improvements range from 0.04 dv to 0.41 dv
- Unit 3 improvements range from 0.08 dv to 0.44 dv
- Unit 4 improvements range from 0.08 dv to 0.44 dv

SCR/SNCR Hybrid with Inherent SO₃ Removal
- Unit 1 improvements range from 0.01 dv to 0.21 dv.
- Unit 2 improvements range from 0.01 dv to 0.20 dv
- Unit 3 improvements range from 0.04 dv to 0.23 dv
- Unit 4 improvements range from 0.03 dv to 0.22 dv

The results again indicate that adding additional NO_x control technology beyond the consent decree consisting of either SCR or SCR/SNCR Hybrid and considering inherent removal of SO_3 does not yield visibility improvement greater than 0.5 dv at any Class I area. Based on the visibility improvement modeled and the total annual cost evaluated in the impact analysis stage of the BART application document, the cost-effectiveness for visibility improvement (annual cost per improvement in visibility, $/dv), was determined for each unit for each Class I area. The resulting cost for installation of additional control technology for each unit is summarized below.

SCR with Inherent SO_3 Removal
- Unit 1 cost range is $489 million/dv to $49 million/dv.
- Unit 2 cost range is $509 million/dv to $53 million/dv.
- Unit 3 cost range is $338 million/dv to $65 million/dv.
- Unit 4 cost range is $341 million/dv to $60 million/dv.

SCR/SNCR Hybrid with Inherent SO_3 Removal
- Unit 1 cost range is $1.2 billion/dv to $78 million/dv.
- Unit 2 cost range is $1.2 billion/dv to $83 million/dv.
- Unit 3 cost range is $732 million/dv to $111 million/dv.
- Unit 4 cost range is $802 million/dv to $111 million/dv.

SJGS Facility Visibility Summary with SCR Inherent Controls and Sorbent Injection

The results of the refined visibility modeling for the SJGS plant, assuming the same sorbent control technology and resulting stack emission rate for all four units, are illustrated in Tables 41-44 of Attachment 6. These tables summarize the scenarios and the maximum visibility (deciview) impact seen at any of the 16 Class I areas at any time over the 2001 to 2003 period. The results of this analysis, using the aforementioned refinements, indicates an improvement in visibility at each of the 16 Class I areas when compared to the baseline (consent decree) scenario or above any of the previously considered SCR control technology scenarios. The highest visibility improvement was at Mesa Verde at 1.34 dv.

The maximum visibility (deciview) improvement seen at any of the 16 Class I areas at any time over the 2001 to 2003 period is illustrated in Table 44 for each scenario. The expected degree of visibility improvement for each unit (on a plant-wide basis) was determined by the difference in the maximum visibility improvement for each receptor at each of the sixteen Class I areas. Again, it is important to note that the control

technology associated with the consent decree formulated the SJGS's baseline case, as well as the baseline case for the individual unit analyses described later. Additionally, the cost-effectiveness for the potential BART control technologies from the BART application were used as the basis and the costs of the sorbent injection technology was added (refer to Part 1 above) to calculate visibility improvement cost-effectiveness in $/deciview ($/dv). Three major scenarios are shown in the visibility improvement cost effectiveness summary in Table 44 for this control technology:

- Pre-consent decree to consent decree.
- Consent decree to SCR NO_x control technology with sorbent/inherent controls.
- Pre-consent decree to SCR NO_x control technology with sorbent/inherent controls.

These maximum visibility improvements between the consent decree and this control technology scenarios range from 0.28 dv to 1.34 dv of expected visibility improvement above the consent decree scenario. The results indicate that adding additional SO_3 control in the form of sorbent injection to the NO_x control technology can yield visibility improvement greater than 0.5 dv at several Class I areas.

Based on the visibility improvement modeled and the total annual cost evaluated as noted above, the cost-effectiveness for visibility improvement (annual cost per improvement in visibility, $/dv), was determined for SJGS over the aforementioned range of visibility improvement. The resulting cost for installation of SCR NO_x control technology and sorbent injection for all four units ranges from $374 million/dv to $78 million/dv.

Unit Specific Visibility Summary with SCR Inherent Controls and Sorbent Injection

The results of the refined visibility modeling for Unit 1, Unit 2, Unit 3, and Unit 4 are illustrated in Tables 45-60 of Attachment 6. These tables summarize the scenarios and the maximum visibility (deciview) impact seen at any of the 16 Class I areas at any time over the 2001 to 2003 period. Similar to results seen for the SJGS facility, the visibility impacts at Mesa Verde, represent the maximum visibility impact at any of the 16 Class I areas.

The maximum visibility (deciview) improvement seen at any of the 16 Class I areas at any time over the 2001 to 2003 period is illustrated in Tables 48, 52, 56, and 60. Again, the expected degree of visibility improvement for each control scenario for each unit was determined by the difference between the consent decree's maximum visibility

improvement for each receptor at each of the sixteen Class I areas and the specific control technology scenario's maximum visibility improvement for each receptor at each of the sixteen Class areas. Furthermore, the same methodology previously described for the SJGS's cost-effectiveness in ($/dv) was used here for each unit.

These maximum visibility improvements between the consent decree and the SCR and Sorbent/Inherent control scenario for each unit are summarized below.

- Unit 1 improvements range from 0.06 dv to 0.67 dv.
- Unit 2 improvements range from 0.06 dv to 0.68 dv
- Unit 3 improvements range from 0.11 dv to 0.89 dv
- Unit 4 improvements range from 0.11 dv to 0.90 dv

Based on the visibility improvement modeled and the total annual cost evaluated as noted above, the cost-effectiveness for visibility improvement (annual cost per improvement in visibility, $/dv), was determined for SJGS over the aforementioned range of visibility improvement. The resulting cost for installation of additional control technology consisting of SCR and sorbent injection for each unit is summarized below.

- Unit 1 cost range is $355 million/dv to $33 million/dv.
- Unit 2 cost range is $377 million/dv to $34 million/dv.
- Unit 3 cost range is $280 million/dv to $34 million/dv.
- Unit 4 cost range is $271 million/dv to $32 million/dv.

SJGS Facility Visibility Summary with SCR/SCNR Hybrid, Inherent Controls, and Sorbent Injection

The results of the refined visibility modeling for the SJGS plant, assuming the same sorbent control technology and resulting stack emission rate for all four units, are illustrated in Tables 61-64 of Attachment 6. These tables summarize the scenarios and the maximum visibility (deciview) impact seen at any of the 16 Class I areas at any time over the 2001 to 2003 period. The results of this analysis, using the aforementioned refinements, indicates an improvement in visibility at each of the 16 Class I areas when compared to the baseline (consent decree) scenario or above any of the previously considered SCR/SNCR Hybrid control technology scenarios. The highest visibility improvement was at Mesa Verde at 0.96 dv.

The maximum visibility (deciview) improvement seen at any of the 16 Class I areas at any time over the 2001 to 2003 period is illustrated in Table 64 for each scenario. The expected degree of visibility improvement for each unit (on a plant-wide basis) was determined by the difference in the maximum visibility improvement for each receptor at each of the sixteen Class I areas. Again, it is important to note that the control technology associated with the consent decree formulated the SJGS's baseline case, as well as the baseline case for the individual unit analyses described later. Additionally, the cost-effectiveness for the potential BART control technologies from the BART application were used as the basis and the costs of the sorbent injection technology was added (refer to Part 1 above) to calculate visibility improvement cost-effectiveness in $/deciview ($/dv). Three major scenarios are shown in the visibility improvement cost effectiveness summary in Table 64 for this control technology:

- Pre-consent decree to consent decree.
- Consent decree to SCR NO_x control technology with sorbent/inherent controls.
- Pre-consent decree to SCR NO_x control technology with sorbent/inherent controls.

These maximum visibility improvements between the consent decree and this control technology scenarios range from 0.15 dv to 0.96 dv of expected visibility improvement above the consent decree scenario. The results indicate that adding additional SO_3 control in the form of sorbent injection to the NO_x control technology can yield visibility improvement greater than 0.5 dv at several Class I areas.

Based on the visibility improvement modeled and the total annual cost evaluated as noted above, the cost-effectiveness for visibility improvement (annual cost per improvement in visibility, $/dv), was determined for SJGS over the aforementioned range

of visibility improvement. The resulting cost for installation of SCR NO_x control technology and sorbent injection for all four units ranges from $592 million/dv to $94 million/dv.

Unit Specific Visibility Summary with SCR/SCNR Hybrid, Inherent Controls, and Sorbent Injection

The results of the refined visibility modeling for Unit 1, Unit 2, Unit 3, and Unit 4 are illustrated in Tables 65-80 of Attachment 6. These tables summarize the scenarios and the maximum visibility (deciview) impact seen at any of the 16 Class I areas at any time over the 2001 to 2003 period. Similar to results seen for the SJGS facility, the visibility impacts at Mesa Verde, represent the maximum visibility impact at any of the 16 Class I areas.

The maximum visibility (deciview) improvement seen at any of the 16 Class I areas at any time over the 2001 to 2003 period is illustrated in Tables 68, 72, 76, and 80. Again, the expected degree of visibility improvement for each control scenario for each unit was determined by the difference between the consent decree's maximum visibility improvement for each receptor at each of the sixteen Class I areas and the specific control technology scenario's maximum visibility improvement for each receptor at each of the sixteen Class areas. Furthermore, the same methodology previously described for the SJGS's cost-effectiveness in ($/dv) was used here for each unit.

These maximum visibility improvements between the consent decree and the SCR and Sorbent/Inherent control scenario for each unit are summarized below.

- Unit 1 improvements range from 0.03 dv to 0.41 dv.
- Unit 2 improvements range from 0.03 dv to 0.41 dv
- Unit 3 improvements range from 0.06 dv to 0.59 dv
- Unit 4 improvements range from 0.06 dv to 0.60 dv

Based on the visibility improvement modeled and the total annual cost evaluated as noted above, the cost-effectiveness for visibility improvement (annual cost per improvement in visibility, $/dv), was determined for SJGS over the aforementioned range of visibility improvement. The resulting cost for installation of additional control technology consisting of SCR and sorbent injection for each unit is summarized below.

- Unit 1 cost range is $570 million/dv to $43 million/dv.
- Unit 2 cost range is $567 million/dv to $44 million/dv.
- Unit 3 cost range is $434 million/dv to $47 million/dv.

- Unit 4 cost range is $458 million/dv to $45 million/dv.

Additional Considerations

As discussed in previous submittals, the visibility results imply that visibility is influenced more by the SJGS's sulfur emissions (both primary SO_2 and additional SO_3 from the catalysts on the NO_x control devices) than by the reduction of NO_x by itself. To illustrate this, Tables 2 and 3 compare the results of SJGS's SCR and SCR/SNCR Hybrid control technology scenario to the results of the SCR and SCR/SNCR Hybrid utilizing sorbent/inherent controls for the class I areas. The results of this comparison indicate that the by adding sorbent injection and including consideration for additional inherent controls to reduce SO_3 emissions, the visibility improvements realized are approximately twice (or more) what they were with SCR with inherent control of the SO_3 formed from the SCR catalyst or SCR/SNCR Hybrid with inherent control of the SO_3 formed from the SCR catalyst alone.

Thus, the visibility results realized by including the sorbent injection and inherent removal of SO_3 emissions, which for the most part have been created due to the oxidation of SO_2 to SO_3 across the catalyst of the SCR, further substantiates that the visibility issues in the area are caused by sulfur emissions and not by emissions of NO_x from SJGS. Part 1 of this document indicated the low cost of the sorbent injection technology which are a fraction of the costs of the NO_x control equipment. While this analysis reviews sorbent injection technology and it's potential for visibility improvement beyond the SCR and SCR/SNCR Hybrid NO_x control equipment by itself, it must be clearly noted that NO_x control equipment have minimal visibility improvement by themselves. Therefore, the minimal visibility improvements discussed in detail in previous submittals and reiterated in this document for the NO_x control equipment do not merit the large capital expenditure required for installation of either SCR or SCR/SNCR Hybrid control technology.

	Maximum Visibility Modeling Results (dv) (98th Percentile, see Note 1)			Visibility Improvements (dv) Maximum Visibility Results	
Class 1 Area	Consent Decree	SCR	SCR w/sorbent	Consent Decree to SCR	Consent Decree to SCR w/sorbent
Arches	1.69	1.72	1.10	NI	0.59
Bandelier	1.56	1.33	0.80	0.23	0.75
Black Canyon	1.15	0.93	0.63	0.22	0.52
Canyonlands	2.26	2.40	1.59	NI	0.67
Capitol Reef	1.81	1.43	1.08	0.37	0.73
Grand Canyon	0.97	0.74	0.53	0.23	0.44
Great Sand Dunes	0.71	0.58	0.40	0.13	0.31
La Garita	0.94	0.72	0.45	0.22	0.49
Maroon Bells	0.56	0.43	0.28	0.13	0.28
Mesa Verde	3.80	6.00	2.46	NI	1.34
Pecos	1.09	1.00	0.66	0.09	0.43
Petrified Forest	0.82	0.74	0.48	0.08	0.34
San Pedro	2.01	2.07	1.13	NI	0.88
West Elk	0.91	0.68	0.43	0.24	0.49
Weminuche	1.48	1.64	0.90	NI	0.59
Wheeler Peak	0.89	0.71	0.50	0.19	0.40

Table 2
SJGS Facility Visibility Improvement Comparison
Variable Ammonia Background and Nitrate Repartitioning

Notes:

1. Maximum of 2001, 2002 and 2003 visibility data.
2. NI = No Improvement

	Maximum Visibility Modeling Results (dv) (98th Percentile, see Note 1)			Visibility Improvements (dv) Maximum Visibility Results	
Class 1 Area	Consent Decree	Hybrid	Hybrid w/sorbent	Consent Decree to Hybrid	Consent Decree to hybrid w/sorbent
Arches	1.69	1.75	1.41	NI	0.28
Bandelier	1.56	1.52	1.11	0.04	0.45
Black Canyon	1.15	1.06	0.87	0.09	0.28
Canyonlands	2.26	2.41	1.95	NI	0.31
Capitol Reef	1.81	1.67	1.43	0.14	0.38
Grand Canyon	0.97	0.87	0.72	0.10	0.25
Great Sand Dunes	0.71	0.72	0.55	NI	0.16
La Garita	0.94	0.85	0.63	0.09	0.32
Maroon Bells	0.56	0.55	0.41	0.01	0.15
Mesa Verde	3.80	5.55	2.83	NI	0.96
Pecos	1.09	1.01	0.82	0.08	0.28
Petrified Forest	0.82	0.79	0.65	0.03	0.17
San Pedro	2.01	2.14	1.47	NI	0.55
West Elk	0.91	0.80	0.61	0.11	0.31
Weminuche	1.48	1.72	1.13	NI	0.36
Wheeler Peak	0.89	0.84	0.63	0.05	0.27

Table 3
SJGS Facility Visibility Improvement Comparison
Variable Ammonia Background and Nitrate Repartitioning

Notes:
1. Maximum of 2001, 2002 and 2003 visibility data.
2. NI = No Improvement

In addition to the prohibitive cost associated with SCR or SCR/SNCR Hybrid control technology, there are other important reasons that LNB, OFA and NN should be considered BART for the SJGS units. First, the LNB, OFA and NN systems just installed to meet the consent decree are state-of-the-art combustion controls. State-of-the-art combustion controls comprising of LNB, OFA and NN technologies were used to form the basis for the BART presumptive limits for NO_x in the BART guidelines. Second, installation of SCR or SCR/SNCR Hybrid control technology requires ammonia to reduce NO_x emissions. Specifically, in a SCR system, ammonia is injected into the flue gas stream just upstream of a catalytic reactor. The ammonia molecules in the presence of the catalyst dissociate NO_x into nitrogen and water. Any unreacted ammonia passes through the reactor and out the stack as ammonia emissions or ammonia slip. This additional ammonia would then be available to add to the ammonia background concentration, chemically react to form nitrates and sulfates, and potentially further increase the visibility impacts at the Class I areas. The additional ammonia slip was not considered in this analysis. Finally, sulfur emissions (i.e., SO_2, H_2S, TRS, H_2SO_4, and/or SO_3) are not subject to BART requirements because New Mexico participates in the WRAP emissions trading program. Therefore, LNB, OFA and NN should be considered BART for NO_x control on the SJGS units.

Conclusion

As noted in this document, PNM's further investigation of sorbent injection control technology to control the additional SO_3 emissions from the SCR or SCR/SNCR Hybrid NO_x control technologies does yield an improvement in visibility at local Class I areas. However, the addition of this technology is solely to mitigate SO_3 emissions created from the oxidation of SO_2 across the catalyst of the SCR or SCR/SNCR Hybrid NO_x control technologies. These technologies by themselves have been shown to have minimal improvement in visibility (less than 0.5 dv) at each of the 16 Class I areas when compared to the baseline (consent decree) scenario.

The conclusion of this study re-iterate and support the overall findings of the previous reports that installation of SCR or SCR/SNCR Hybrid NO_x control technologies at the SJGS provide minimal visibility improvements by themselves and would require significant capital expenditure and modifications that will impact many areas of the plant including boiler draft systems, air heater performance, SO_3 emissions, and ash handling. The results from the analyses further substantiate that the addition of SCR or SCR/SNCR Hybrid NO_x control technologies does not yield a benefit nor meet the intended goal of BART. Specifically, these analyses indicate:

- The addition of SCR or SCR/SNCR Hybrid technology with inherent removal on a plant-wide basis shows only one instance of an improvement greater than 0.5 dv (Capital Reef Class I area at 0.54 dv). All other Class I areas show less than a 0.5 dv improvement for all Class I areas including the four Class I areas located in New Mexico. In fact, the plant wide analyses with inherent removal have shown continued visibility degradation at Mesa Verde. Individual unit analyses have shown visibility improvements less than 0.5 dv at all Class I areas.
- Any visibility improvement illustrated at a class I areas greater than 0.5 dv due to the installation of sorbent injection should not be considered a solution. Instead, it should be realized that the consideration of sorbent injection is to mitigate the secondary pollutant affect of the SCR or SCR/SNCR Hybrid technology.
- Both the total annual costs evaluated and the cost-effectiveness ($/dv) are prohibitive given the minimal improvements realized.

Therefore, as previously noted, given the overall cost of the SCR or SCR/SNCR Hybrid technology and minimal visibility improvements for these technologies by themselves, the recommended BART control for SJGS is LNB, OFA, and a NN for NO_x control and PJFF for PM control.

ATTACHMENTS 1-6

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